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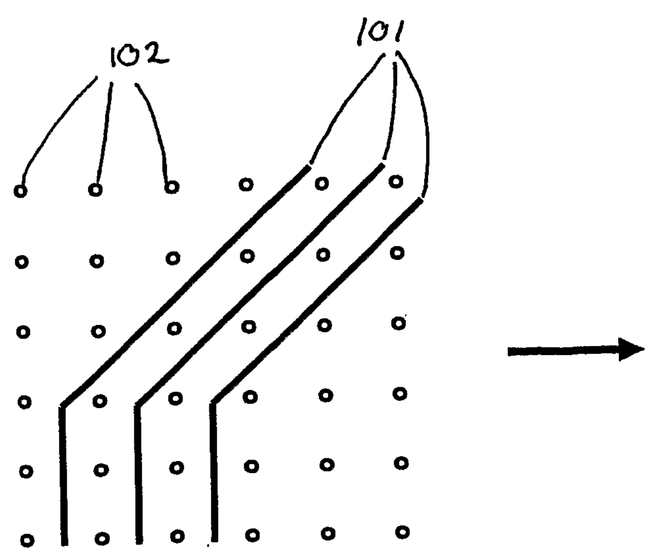

(57) Abstract: A method for printing multiple layer structures, such as printed circuit boards, or flexible substrates: a first print pattern is printed to form a first layer, which is subsequently imaged to measure the displacement vectors of fiducial marks in the first print pattern; the vectors are then applied to the second print pattern to ensure that the second layer is printed in registration with the first layer.

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METHOD OF PRINTING

This invention relates to printing of multilayered structures, and in particular to printing onto flexible substrates.

Web based processing and manufacturing provides the advantage that processing stages can be performed continuously on a flexible substrate, eg a polyimide sheet which can be supported on rollers. A problem associated with flexible substrates however is that they can exhibit dimensional changes according to ambient conditions such as temperature and humidity. A 10cm wide strip of polyimide can expand or contract by 3μm per degree centigrade change in temperature for example.

Printing onto a flexible substrate can also give rise to dimensional changes in that substrate. The wetting (and drying) of a substrate by a print fluid, or the residual stresses in a deposited layer will tend to cause strains in the substrate. Dimensional changes caused by printing onto a substrate may also be non-uniform and can be pattern dependent. The structure formed after printing, curing and heating stages may be significantly distorted relative to the intended print pattern.

Such distortions in the substrate are particularly troublesome with multiple layer structures. In this case, the substrate may deform between the depositions of successive layers. In many such applications, it is essential that adjacent layers are located in precise register with each other; this is especially the case where the structures must be electrically or physically connected.

Accordingly the present invention consists in a first aspect in a method for printing onto a flexible substrate comprising: printing a first print pattern onto said flexible substrate; subsequently imaging the surface of the flexible substrate; comparing said imaged surface with said first print pattern; calculating, based on the results of said comparison, a pattern correction mapping; applying said mapping to a second print pattern to form a corrected second print pattern and printing the corrected second pattern onto said flexible substrate.

In this way, any deformation of the substrate which occurs between the printing of the first and second patterns can be compensated for, and the

second pattern can be printed in precise alignment with the structure formed by printing the first pattern.

The print pattern for each successive layers can thus be transformed to take into account the distortion of the immediately preceding layer.

In a further aspect, the present invention consists in a method for forming a structure on a flexible substrate by printing a succession of patterns on the substrate to form respective printed layers, the method comprising the steps of printing a first print pattern on said flexible substrate, thus forming at least in part a first printed layer; measuring displacement vectors of two or more points in the first printed layer relative to corresponding points in said first print pattern, said displacement vectors representing distortion in the substrate caused by formation of the first printed layer; applying the displacement vectors to a second print pattern to form a corrected second print pattern; and printing said corrected second print pattern on the flexible substrate to form a second printed layer overlying the first printed layer.

Preferably, the step of applying the displacement vectors includes the step of interpolating or interpolating vectors.

Advantageously, the formation of the first printed layer includes a processing step after printing of the first print and before measurement of displacement vectors.

The correction provided by the present invention is particularly important when printing functional components such as circuit boards, to ensure correct connection of components between printed layers. In the manufacture of a printed circuit boards (PCBs), the printed patterns might correspond to:

- Flood coat of insulator on a base substrate
- Layer of conductive tracks
- Layer of components eg. Resistors and capacitors
- Layer of insulator between tracks
- Via layer
- Insulation in between vias
- New layer of conductive tracks

It will be appreciated that a correction mapping need not be derived for each printed pattern or layer, and that the process can be performed selectively for those layers prone to alignment errors.

The first printed pattern preferably includes a plurality of fiducial marks to assist with the comparison of the imaged surface with said first print pattern. The marks are preferably easily identifiable by the imaging process. Crosses or concentric circles for example are more readily recognised by many image recognition algorithms. The marks may be positioned substantially randomly, where space allows in the printed pattern, or may be positioned near critical areas of the image, to ensure greatest accuracy in those areas.

The fiducial marks will typically be included in the printed pattern solely for the purpose of detecting distortion in the printed pattern, however, in certain applications it may be possible to use elements of the pattern itself as fiducial marks. Taking the example of a printed circuit board, it may be possible to use tracks, resistors, capacitors and other circuit elements as recognisable markings from which a determination of distortion can be obtained. A combination of dedicated and functional fiducial marks can be employed, and these could be assigned different weightings when calculating a correction mapping.

The printed pattern may advantageously be applied by inkjet printing of an active fluid. A wide variety of fluid processable substances are known to be suitable for inkjet printing, which are capable of forming structures such as conductive tracks and components such as capacitors, resistors or transistors. The use of inkjet printing reduces the cost of forming structures on flexible substrates and offers reduced startup time for rapid prototyping. Methods of forming PCBs are known from WO02/47447, where barriers are formed using inkjetting of curable ink, followed by the filling of the region interior the barriers with conductive fluid, but many other techniques of course exist.

The present invention will now be described by way of example with reference to the accompanying drawings in which:

Figure 1 shows a first print pattern

Figure 2 shows an image of the printed substrate

Figure 3 shows an example displacement vector field corresponding to the substrate distortion

Figure 4 shows example data produced by a comparison of fiducial marks in the print pattern to those of the printed structure

The print pattern of Figure 1 includes a plurality of electrical tracks 101 and a plurality of circular fiducial marks 102 disposed in a grid. After having been printed on a flexible substrate, and possibly subject to a number of physical or chemical processes such as drying, curing, heating etc. the printed substrate is shown in Figure 2. The fiducial marks of the print pattern 102 are shown in grey for comparison. It can be seen that some deformation of the substrate has occurred, and that the printed fiducial marks 202 no longer correspond in position to marks 102. Similarly, the tracks 201 deviate from the intended those of the print pattern 101.

By comparing the original pattern (the print data) to the actual printed layer resulting on the substrate (photographed or scanned data for example), differences in position of corresponding fiducial marks can be determined. This will commonly be of the form of a displacement vector field as illustrated schematically in Figure 3, where the displacement vectors 302 are clearly displayed. Figure 4 shows example data generated by such a method: the fiducial marks of the print pattern 102 are disposed in a grid making the distortion of the substrate visible from the displacement of fiducial marks in the printed structure 402. Utilising a linear or non-linear interpolation scheme, the displacement vectors for intermediate points of the printed layer may be determined. Suitable interpolation methods such as spline interpolation or bicubic interpolation will be well known to those skilled in the art. Conventional PCB patterns are produced using a stylus or plotter and so are stored in a vector format such as HPGL or Gerber file format. Thus, this vector displacement field may be easily applied to the print pattern for the next layer to take account of the substrate distortion resulting from the formation of the previous layer. However, the correction mapping may equally be applied to a rasterized PCB pattern. The resulting print pattern may then be printed using a conventional stylus or plotter technique or may be rasterized for inkjet printing or laser-scanning.

The correction mapping compensates for changes in topology to the substrate and hence the printed layer and may comprise stretch

transformations, skew transformations, rotations, and keystoning for example. The mapping may be highly non-linear and may be pattern dependent.

The correction mapping is applied to a second print pattern to be printed, at least partially, on top of the first printed layer, and results in improved alignment between the first and second printed layers.

Pattern comparison and correction mapping have been described in two dimensions, however the present invention can equally extend to three dimensions. For example distortions in the thickness or depth of the first printed layer could be detected and compensated for. Stereoscopic imaging or other appropriate depth imaging techniques can be used to detect distortions in the z or height dimension.

While the invention has been described above with reference to circular fiducial marks disposed in a grid, the invention may be easily adapted to a non-regular pattern of fiducial marks. The distribution pattern may advantageously be adapted so that there is greater resolution in areas where registration between adjacent layers is of particular importance. The interpolation methods necessary to generate the correction pattern with a non-regular distribution of fiducial marks are well known in the art and would require little adaptation.

Equally, the fiducial marks need not be of a circular shape and those skilled in the art of PCB design will appreciate that any standard fiducial marks may be utilised. Further, with more sophisticated pattern recognition software and hardware it is envisaged that functional components of the structure may themselves serve as fiducial marks, thus using the limited space on the substrate more efficiently.

Those skilled in the art will appreciate that where printing of a pattern is referred to herein the invention may utilise a variety of methods capable of transferring an image to a substrate in order to form a structure.

CLAIMS

1. A method for printing onto a flexible substrate comprising: printing a first print pattern onto said flexible substrate; subsequently imaging the surface of the flexible substrate; comparing said imaged surface with said first print pattern; calculating, based on the results of said comparison, a pattern correction mapping; applying said mapping to a second print pattern to form a corrected second print pattern and printing the corrected second pattern onto said flexible substrate.

2. A method according to Claim 1, wherein said first pattern includes a plurality of fiducial marks which can be identified in said imaged surface.

3. A method according to Claim 1 or Claim 2, wherein said fiducial marks serve the sole purpose of pattern comparison.

4. A method according to Claim 2 or Claim 3, wherein said fiducial marks are distributed substantially randomly in the pattern.

5. A method according to Claim 2 or Claim 3, wherein said fiducial marks are distributed to maximise accuracy in alignment critical areas of the pattern.

6. A method according to any preceding claim wherein said fiducial marks comprise crosses or concentric circles.

7. A method according to Claim 1 or Claim 2, wherein selected elements of the first print pattern are used as fiducial marks which can be identified in said imaged surface.

8. A method according to any one of the preceding claims, comprising the further steps of imaging the surface of the flexible substrate; comparing said imaged surface with said second corrected print pattern; calculating, based on the results of said comparison, a pattern correction mapping; applying said mapping to a third print pattern to form a corrected third print pattern and printing the corrected third pattern onto said flexible substrate.

9. A method according to any one of the preceding claims in which the successively printed patterns combine to form a functional structure.

10. A method according to Claim 9 in which the functional structure comprises electronic circuitry.

11. A method according to any of the preceding claims wherein the comparison step comprises measuring the displacements of the fiducial marks relative to their respective locations in the print pattern, thus generating a plurality of displacement vectors.

12. A method according to Claim 11 wherein the calculation step comprises interpolating the displacement vectors to create a vector field.

13. A method according to Claim 12 wherein the calculation step utilises linear interpolation.

14. A method according to Claim 12 wherein the calculation step utilises non-linear interpolation.

15. A method for forming a structure on a flexible substrate by printing a succession of patterns on the substrate to form respective printed layers, the method comprising the steps of printing a first print pattern on said flexible substrate, thus forming at least in part a first printed layer; measuring displacement vectors of two or more points in the first printed layer relative to corresponding points in said first print pattern, said displacement vectors representing distortion in the substrate caused by formation of the first printed layer; applying the displacement vectors to a second print pattern to form a corrected second print pattern; and printing said corrected second print pattern on the flexible substrate to form a second printed layer overlying the first printed layer.

16. A method according to Claim 15, wherein the step of applying the displacement vectors includes the step of interpolating or interpolating vectors.

17. A method according to Claim 15 or Claim 16, wherein the formation of the first printed layer includes a processing step after printing of the first print and before measurement of displacement vectors.

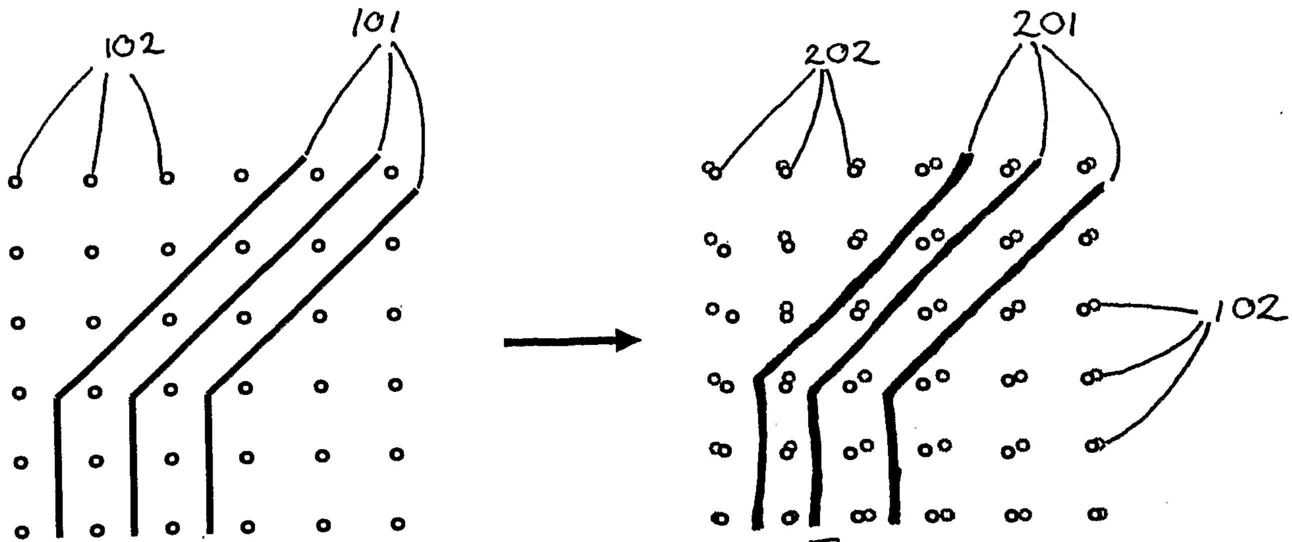

FIG 1

FIG 2.

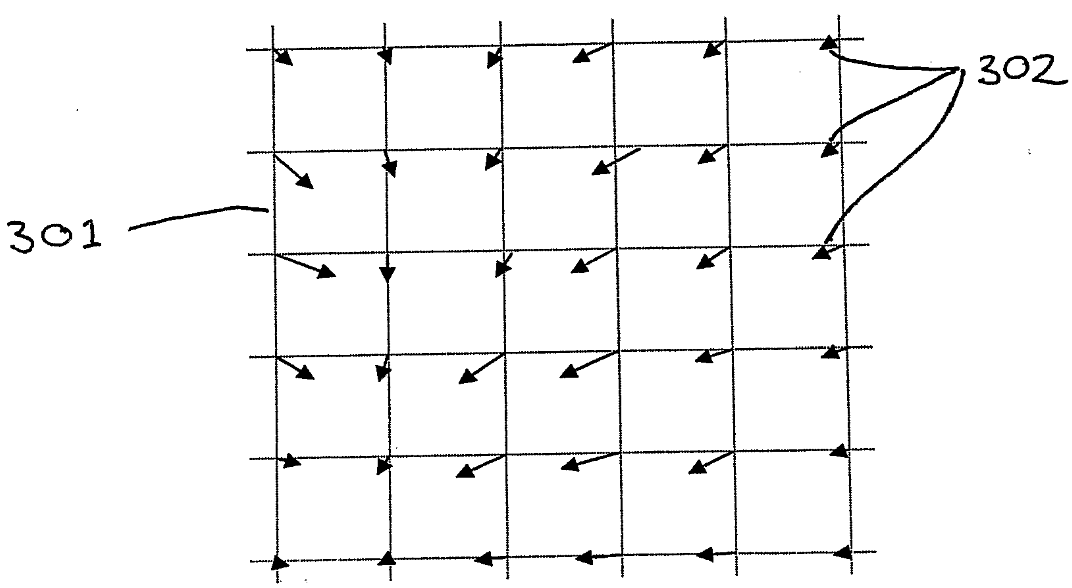

FIG 3.

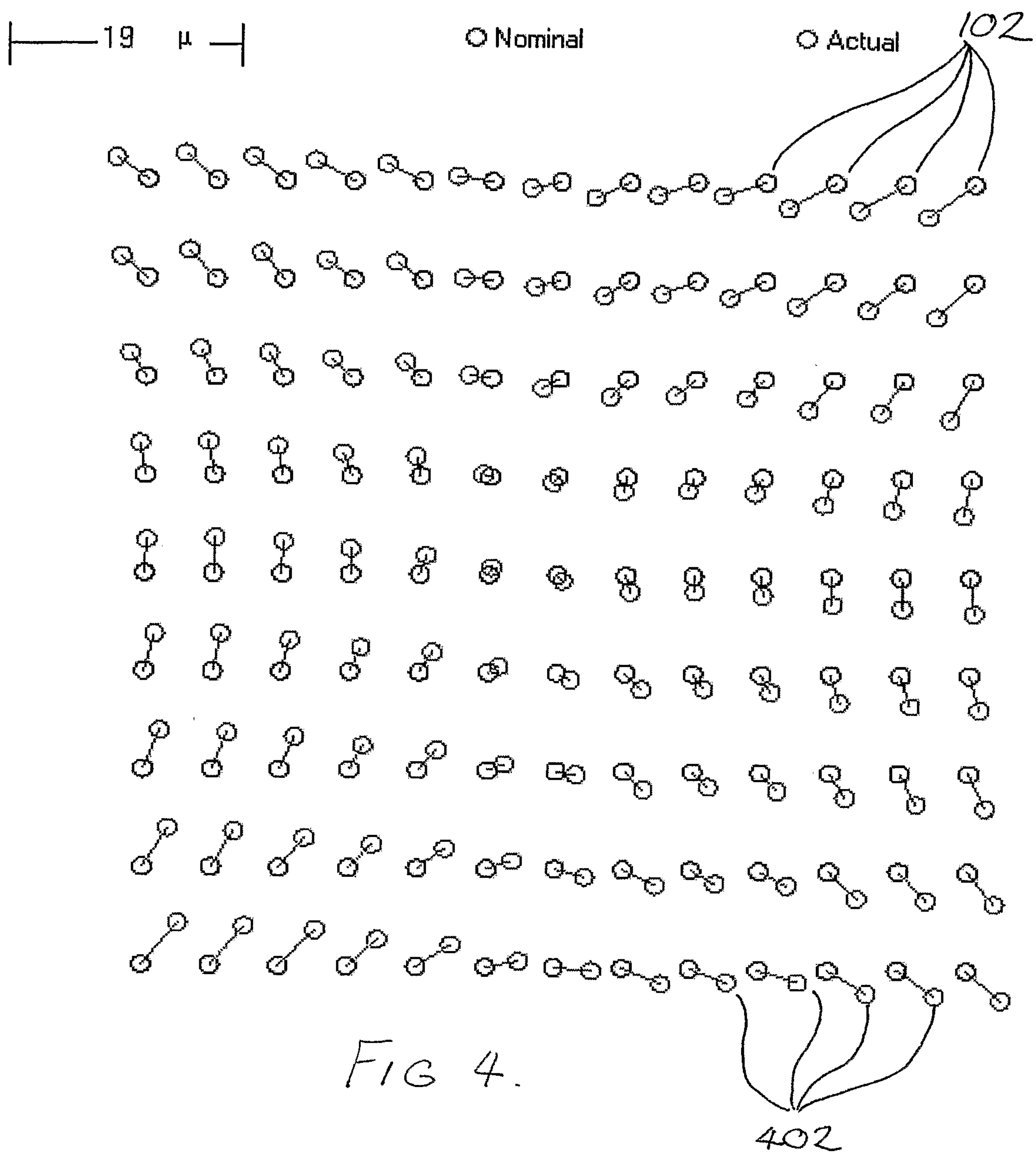

FIG 4.